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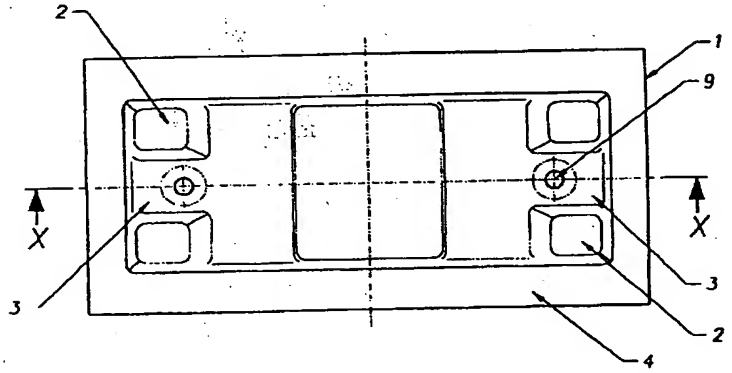
(54) **PROCEDE ET APPAREIL UTILISES POUR COULER DES METAUX**

(54) **METAL CASTING PROCESSES AND APPARATUS**



(57) Appareil automatisé servant à couler des métaux, par exemple du zinc. L'appareil comprend un chariot à plateau tournant qui transporte les moules à quatre postes successifs distincts, soit un poste de coulée (290) où le métal est coulé au moyen d'un caniveau (50), un poste d'écrémage (291) où une écumoire contrôlée par un robot enlève les crasses, un poste de transfert où les moules contenant le métal fondu sont retirés au moyen d'un pont roulant pour être placés dans un bac de refroidissement à un endroit essentiellement libre de

(57) Automated apparatus for the casting of metal such as zinc which includes an indexed carousel for indexing moulds through four stations. The stations are a casting station 290 where metal is cast via a launder 50, a skimming station 291 where an automatic robot controlled skimmer removes dross, a transfer station from which moulds containing molten metal are removed by an overhead crane to be placed in a cooling tank at a location substantially free of vibration and cooled moulds are returned by the crane to the transfer

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vibrations, les moules refroidis étant retournés au moyen de l'appareil de levage au poste de transfert, ainsi qu'un poste de démoulage (293) où les lingots coulés (200) sont retirés des moules par un autre pont roulant, après quoi les moules vides sont retournés au poste de coulée. Les lingots sont retirés des moules au poste de démoulage au moyen d'un mécanisme qui retire les broches coulées avec les lingots et les remet dans les moules vides.

station and a delivery station 293 where the cast ingots 200 are removed from the moulds by another overhead crane and the empty moulds are recycled to the casting station. The ingots are lifted from the moulds at the delivery station by a mechanism which removes pins cast with the ingots and returns them to the empty mould.

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ABSTRACT

Automated apparatus for the casting of metal such as zinc which includes an indexed carousel for indexing moulds through four stations. The stations are a casting station 290 where metal is cast via a launder 50, a skimming station 291 where an automatic robot controlled skimmer removes dross, a transfer station from which moulds containing molten metal are removed by an overhead crane to be placed in a cooling tank at a location substantially free of vibration and cooled moulds are returned by the crane to the transfer station and a delivery station 293 where the cast ingots 200 are removed from the moulds by another overhead crane and the empty moulds are recycled to the casting station. The ingots are lifted from the moulds at the delivery station by a mechanism which removes pins cast with the ingots and returns them to the empty mould.

Title: METAL CASTING PROCESSES AND APPARATUS

Field of the Invention

The invention relates to apparatus and processes for the casting of metals. In preferred non-limiting aspects it relates to methods and apparatus systems for automatic casting of metals, particularly non-ferrous metals such as lead, tin, zinc, aluminium and alloys and to particular components of automatic casting systems such as launders, pin removal systems, dross skimming devices.

Background of the Invention

A typical known system for the semi-automatic casting of zinc involves the use of a moving launder which is indexed to cast metal into moulds arranged around the launder in semi-circular fashion. The cast metal is skimmed manually and the moulds do not move between the time the zinc is cast until such time as the metal is solidified. As there is a limit to the number of moulds which can be arranged around a launder, the rate of casting of metal is limited by the number of moulds which can be placed near the launder and the rate of cooling for metal. Most systems of this type which have a maximum capacity of 15 tonnes per hour. On an industrial scale, as 15 tonnes per hour is not high there is considerable need for the development of approaches which lead to higher production rates and do not suffer to the same extent from the crowding problems associated with arrangement of a group of moulds in a semi-circle around a launder.

Furthermore, the individual elements of such commercially known processes such as the skimming of dross, the formation of dross during casting and the removal of casting pins after the cast metal has solidified all involve a range of problems which are summarised below.

In the case of dross formation during casting, it is well known that agitation and exposure to the atmosphere of molten metals and alloys tends to cause the formation of drosses and scums during the pouring process largely as a result of oxidation reactions. This inevitably causes efficiency losses and reduced cost efficiency because the skimmed dross needs to be returned to the melting furnace to recover the metal value contained therein. In current pouring practice, the molten metal or alloy is typically poured into a variety of moulds, eg moulds for producing ingots or blocks which may range from a few kilograms to 5,000 kilograms in weight. In one approach molten metal is poured through funnels

and down tubes located at the ends of launders thereby creating a vortex effect in the down tube and so drawing and trapping air in the melt with resultant oxidation and dross formation. Thus there is a need for development of a pouring approach which reduces the rate of formation of dross as a result of pouring.

With regard to skimming of dross from molten metals, in conventional practice such skimming is normally carried out with hand operated paddles. This is dangerous for the operator and it requires a significant degree of dexterity to be exercised by any operator to avoid any partial freezing or sticking of a paddle to a mould or ingot as the paddle is being drawn over the molten metal surface. This is particularly true for the higher melting point metals for several reasons. One of these is that the casting of such metals tends to be carried out at temperatures relatively close to their melting points or melting ranges thus creating a predisposition towards premature and partial freezing or solidification when compared with some other metals which may be processed at temperatures well above their melting points. The problem of paddles sticking or jamming worsens when pouring time is extended or with any decrease in temperature of molten metals and/or moulds during pouring.

Another contributing factor in premature freezing problems is linked to the differences in specific heat characteristics between the molten metals being poured and the mould materials used, most commonly cast iron or steel. In the case of lead, for instance as the latter's specific heat is about a quarter that of iron, an unheated mould may be expected to have a quite chilling effect. Thus there is a need for automatic skimming devices which do not suffer from the disadvantages associated with manual skimming.

Whilst automatic skimming devices are known, by and large these have only been moderately successful. Typically, in this sort of device, one or more paddles, often two paddles, skimming the molten surface in opposite directions operated by robots or other mechanisms are employed. In the two paddle arrangement, the paddle picks up skimmed dross for disposal after converging at the finish of their skimming paths. The earlier mentioned partial freezing problems, especially along the sides of the moulds are not eliminated and any resultant sticking or jamming is not conducive to smooth production. In addition there is a tendency for bands of dross not being skimmed off and remaining along the sides of any ingots or blocks produced. In the case of lead, for instance, the problem may be further aggravated by the physical nature, more specifically the tough and sticky texture of the dross formed.

As for the removal of cast blocks from moulds and also the removal of lifting pins cast in with the blocks or ingots, manufacturers are typically casting blocks or ingots in water cooled steel moulds and removing them by inverting the moulds or "casting in" removable lifting tools such as tapered pins or hooks.

In the majority of the block casting plants today, cast inside hooks are used to remove or demould the blocks from the moulds. This is the oldest and most obvious method. However, it is not easy to remove cast in hooks from the sides of the block where they are trapped by metal shrinkage and surrounding metal flashings. These flashings occur when molten metal runs between the hook and the wall of the mould. To remove the cast inside hooks, an operator hammers the hooks out normally with a five kilogram sledge hammer requiring an average of five blows to dislodge the hooks depending on the amount of flushing behind the hooks. The operator then proceeds to remove all flashings from the cavity left by the hook using a sharp chisel with a long handle. As this operation demands great amounts of time and labour as well as causing unacceptable levels of operator injuries, there is clearly scope for the development of more efficient techniques.

In the case of tapered lifting pins which are used instead of side hooks in some installations, pins which are tapered from a major diameter at the bottom to a minor diameter at the upper end and provided with an enlarged head are used. These are placed in the mould and the metal cast around the pins. Following cooling of the metal, in some semi-automated operations, the block or ingot is lifted off the mould by a lifting grabber which hooks on the top of the pins and transfers it to a pin press which removes the pins from the block by pushing the pins down through the block into a collecting tray. After the block is taken away, the operator manually carries the lifting pins back to the mould for a new pouring cycle with the consequence risk of injury as the pins are often of heavy construction, typically weighing 15 to 20 kilograms each and are at high temperature. Thus there is a need for an alternative automated approach which does not require the operator to lift the pins manually.

Disclosure of the Invention

The invention provides in one aspect apparatus for the casting of metals having a sequential drive for indexing moulds provided thereon to a plurality of stations, the plurality of stations including:-

a casting station for casting molten metal into a mould;

a transfer station provided with transfer means for transferring a mould containing molten metal cast into the casting station to a cooling facility separate from the sequential drive and return means for returning a cooled mould containing solidified metal ingot from the cooling facility to the sequential drive; and

a delivery station provided with removal means for removing the solidified metal ingot from the sequential drive leaving an empty mould on the sequential drive for return to the casting station.

Preferably the apparatus includes a skimming station located between the casting station and transfer station. At the skimming station dross may be removed from the molten metal cast into the mould either manually or with automatic machinery. The dross may be removed with one or more paddles. The one or more paddles may include a curved or spoon shaped section for dross removal. They may be operated by skimming off dross on the surface of the metal using one or more strokes. The one or more paddles may be sprung or unsprung. A robot or other automatic equipment may be used to stroke the one or more paddles.

Heating means may also be provided in association with each paddle to melt localised frozen or solidified material at the top and or sides of metal cast in a mould to provide a clean path for the stroking paddle. The heating means may take the form of one or more flame nozzles. Most suitably two flame nozzles are provided along opposed sides of each paddle. The flame provided by the nozzles may be provided by the combustion of hydrocarbon gas and oxygen. The oxygen may be provided as air or oxygen of higher purity. Suitably the oxygen is at least 80% pure.

The provision of flames that impinge on the molten metal in front of the paddles can furnish heat across the whole of the molten metal surface. Thus the problems of sticking and jamming caused by freezing within the moulds are ameliorated.

Suitably the return means is arranged to return cooled moulds to the sequential drive at the transfer station.

The sequential drive may include a driven rotating platform or carousel. The moulds may be placed on the platform and indexed to the different stations. The platform may include a plurality of cradles for receiving the moulds. Suitably there are four or more cradles. The sequential drive may include control means to limit the disturbances to molten metal

cast into moulds on the drive. The control means may include an electronically controlled servo-motor. It may maintain the moulds at constant speed between phases of acceleration and deceleration. It may accelerate and/or decelerate the moulds according to a velocity versus time relationship which is substantially sinusoidinal ie during acceleration the relationship can be expressed as sin (f(t)) where t is time over the acceleration period starting from a velocity of zero. This similarly applies for deceleration. The cooling facility is provided to allow time for cooling and solidification of the metal in the moulds in a still area which provides that the moulds are protected from disturbances by vibrations or other movements in order to facilitate high quality casting of ingots. It is well known that vibration of moulds during cooling is liable to create undesirable ripples and fins on the surface of the cast product.

The cooling facility may be any area substantially isolated from vibration or other disturbance. It may include cooling means to speed up the cooling of moulds at a rate greater than would be expected if the moulds were simply left to cool in the air at ambient temperature.

The cooling means may provide for the moulds to be in contact with a cooling fluid such as water. The cooling fluid such as water may be circulated around the moulds by a pump or other appropriate means. The cooling means may include a tank. There may be a plurality of tanks. Each tank may be of a size suitable to accommodate a single mould or more than one mould for cooling. Most suitably the tanks and moulds are constructed so that the lip provided on opposed sides of the moulds may rest upon or be otherwise supported by the sides of the tank. In a particularly preferred arrangement the cooling facility includes a plurality of tanks arranged in a straight line.

The transfer means may include an overhead crane or any other suitable pick and place apparatus. It may include one or more overhead rails for moving the crane from a location above the sequential drive. At this location it can pick up a mould containing molten metal. The crane is then driven along the rails to the cooling facility. Thus the crane may include a drive motor. Suitably it will be an electrical servo-motor. At the cooling facility the mould containing molten metal is deposited. Subsequently, a mould with cooled metal is picked up to be returned to the sequential drive.

The servo-motor for the crane may be operated by crane control means. The crane control means may accelerate and/or decelerate the moulds according to a velocity versus

time relationship which is substantially sinusoidinal. It may maintain the crane at constant speed between phases of acceleration and deceleration.

Suitably the crane includes mould gripping means which are suspended from the crane. The mould gripping means may be pivotally attached to the crane. The mould gripping means may be adapted to pivot contrary to the direction of acceleration or deceleration.

The invention also provides a launder for casting molten metal into a mould. The launder may be tiltable. It may include a compressible support such as a spring loaded support or other equivalent eg a hydraulically, electrically or pneumatically actuated support. The launder support mechanism may be associated with control means for controlling the operation of a valve. The control means may take the form of a lever which opens the valve. The level of molten metal in the tilting launder may be varied or, more preferably kept constant throughout the pouring process regardless of the incoming flow rates. This may be achieved by actuating the valve in the down pipe by a lever operated by a spring loaded launder support. As the molten metal fills the launder, including funnel and down pipe the extra weight compresses the launder support mechanism and begins to rotate the lever that opens the down pipe valve and so causes increased flow. As the flow increases the level of metal in the launder (and the weight of the launder) decreases thereby decompressing the launder support system which in turn causes closure of the valve and a rise in the level of the molten metal in the launder. Thus self regulation of the metal level in the reservoir is achieved.

Where it is desired to maintain the level of metal constant the opening of the valve is arranged to be proportional to the weight of the launder and hence proportional to the flow rate of the incoming molten metal. Therefore variations in the flow rates through the launder do not necessarily affect the level of the molten metal reservoir.

The level in the launder may be proportional to the loading force in the support mechanism. The launder is suited to both continuous and batch production.

Where the launder is used in association with the apparatus for casting metals of the invention it will be located at the casting station. The launder will operate to sequentially fill moulds indexed to the launder by a sequential drive. It may be associated with sensing means which sense the level of metal cast into each mould. The sensing means may actuate the valve to limit the amount of metal cast into each mould.

In operating casting apparatus according to the invention it is preferable to cast each metal ingot around pins which are used to facilitate removal of the ingot from a mould. For this purpose the pins may be provided with holding means which can be readily grasped or otherwise held by conventional equipment for pulling the ingots out of a mould. The holding means may include an enlarged head portion. Two such pins per ingot are preferred. The pins may be tapered. They may be placed in a mould prior to casting with the major diameter of the pin located at the bottom of the mould and the minor diameter at an upper portion of the pin. The enlarged head portion is provided above the minor diameter portion. The pins may be manually removed from cast ingots in the conventional manner, namely with a sledge hammer. Alternatively, an automatic mechanical device may be used to perform this function.

Of course, removal of the pins only occurs after removal from the sequential drive by the removal means.

In an alternative arrangement according to one aspect of this invention the tapered pins may be placed in the mould with the minor diameter placed to sit on the bottom of the mould such that the greater diameter portion extends out of the top of the ingot. In this configuration the pins are constructed so that the holding means, if holding means are required, are attached above or form part of the greater diameter portion. With this arrangement it is possible to hold a pair of pins within an ingot while at the same time pulling upwardly on the pins to lift the ingot out of a mould and/or to lift the ingot including mould from the sequential drive. This is achieved by exerting pressure as a compressive or expansive force on the ingot through the pins in order to provide sufficient friction between the ingot and pins as to prevent them being pulled from the ingot until the compressive or expansive force has been released.

A preferred form of pin removal apparatus which can be used in this manner includes attachment members in the form of hooks which are adapted to hold the ingot by way of attachment to the pins, and to exert force on the ingot through the pins to create a frictional engagement between the pins and the ingot. The force may be applied via a toggle connected to the hooks.

The pin removal apparatus may also include pushing means. The pushing means may serve to push the ingot from the pins when force across the pins and hence the frictional engagement is released. The pushing means may include one or more hydraulic or pneumatic cylinders or electric actuators. Most suitably it includes two such cylinders.

In a further aspect the invention provides a method for the casting of metals including the steps of:-

indexing a mould in series on a rotating carousel to a casting station, a skimming station, a transfer station and a delivery station;

casting molten metal into the mould at the casting station;

skimming dross from the molten metal at the skimming station;

transferring the mould containing molten metal from the transfer station to a cooling station remote from the transfer station and replacing it at the transfer station with a cooled mould containing a solidified metal ingot from the cooling station;

removing the solidified metal ingot from the cooled mould at the delivery station; and

returning the cooled mould less solidified metal ingot to the casting station.

Brief Description of the Drawings

Figure 1a shows a plan view of a mould;

Figure 1b is an elevation of a mould section taken through the line x-x in Figure 1a;

Figure 1c is a side elevation of the mould of Figure 1a sitting in a cooling tank;

Figure 2a shows a side elevation of a launder;

Figure 2b shows a front elevation of a launder;

Figure 3 shows a side elevation of a launder;

Figure 4 shows a front elevation of a launder;

Figure 5 shows a perspective view of an automatic skimming device;

Figure 6 shows a side elevation of a cast block pin removal device;

Figure 6a shows a plan view of the device of figure 6;

Figure 7 shows a plan view of a block casting machine;

Figure 8 shows a side elevation of the casting machine of Figure 7;

Figure 9 shows a front elevation of an overhead crane;

Figure 10 shows a side elevation of a conveyor and pin block removal device; and

Figure 11 shows a partial front elevational view of the device of Figure 10.

Detailed Description of the preferred Embodiments

In the following description, it should be noted that common reference numerals appearing throughout the drawings refer to similar elements.

Referring to Figures 1a, 1b and 1c, a typical mould construction 1 is shown. The construction shown in these drawings is one which is particularly suitable for the casting of zinc. However, it is to be understood that other metals and other mould constructions may be appropriate for the various forms of practice of this invention.

The mould 1 will generally be formed of a conventional metal material such as steel or cast iron having been moulded or stamped or fabricated as a single piece. It includes a peripheral lip portion 4 provided around the top of the four sides of the mould, the sides being slightly angled to the vertical to create a wedge shaped cast block which can be readily removed therefrom.

The floor of the mould includes a plurality of recesses 2 and raised portions 3 which serve to allow access to fork truck tines. Where the mould is designed for casting of a metal such as zinc, it may typically have a capacity to handle a one tonne zinc block.

The raised portions 3 in the mould also provide a base to rest two pins 9 which will ultimately be used to assist in handling the cast block when the metal has cooled.

The pins 9 include an enlarged head 8 and a tapered body 7. An annular recess 10 formed between the head 8 and tapered body 7 provides anchor points for hooks used to lift the cast block out of the mould.

During cooling of metal in the mould 1, the mould is suspended in a cooling tank 12 by way of the lip 4 for sitting on the upper edge 14 of the walls of the tank. Cooling fluid such as water is passed through the tank and heating elements provided in the tank lid 13 serve to control the rate of surface cooling and reduce imperfections in the surface of the molten block.

Referring to Figure 2, there is shown a launder generally designated 20 which includes an elongate channel reservoir 22. This is provided at one end with a funnel 23 provided with a downpipe 24 having an outlet 25.

The reservoir 22 is pivotally mounted on the pivot mount 26 near the end opposite the funnel. A generally centrally located lifting cylinder 27 is coupled to the reservoir 22 via the pivotal coupling connection 28. It should be noted that the pivotal coupling is in the form of a slot which permits a degree of up and down movement of the reservoir relative to the lifting cylinder.

A pair of support springs 29 proximate the funnel, resiliently support that end of the reservoir, the degree of compression of the springs being dependent upon the level of metal 41 in the reservoir.

The springs surround the support rod 30 which extend through the funnel and above the launder to be joined via pivot connections 32 to lever arms 31. The lever arms 31 pivot about the central pivot 33 and are connected at the other end to the hydraulic cylinder 38.

The hydraulic cylinder is in turn connected to the valve stem 39 terminating in the valve 40 for closing off the opening 25.

Referring to Figures 3 and 4, the reference numerals used to identify the various launder elements are changed because the detail of the launder construction differs significantly from that shown in Figures 2a and 2b although the overall principal of operation remains essential the same.

The launder 50 includes an elongate reservoir 51 terminating in a funnel 52 provided at one end. The opposite end of the launder is mounted on the pivot mount 53 and a hydraulic cylinder 54 is connected to support an intermediate position along the launder via the pivot mount 55 provided on the bottom of the hydraulic cylinder and the pivot mount 56 between the cylinder and launder. Again, the pivot mount 55 includes a slot to allow some up and down play between the reservoir and the hydraulic cylinder.

The launder is provided with a v-shaped refractory lined channel 57 to deliver molten metal to the funnel 52.

The tiltable reservoir, is constructed so that it may tilt in response to the level and hence weight of molten metal in the reservoir. This is to control the ball valve 71 for opening and closing the funnel.

For this purpose the valve stem 70 which is connected to the attachment bar 67 is moved up and down by the bar in response to the level of metal in the reservoir to control flow through the valved mouth of the funnel.

An attachment bar 67 is mounted on and pivots about the pivot bearing 66 with the degree of pivoting being limited by the dead stop 61 resting against the underneath of the reservoir. A pair of support wheels 62 which are adapted to rest on the lip of a mould provides support to the attachment bar 67 and hence the launder.

A spring 59 is used to control the degree of pivoting of the attachment bar about the pivot bearing 66. A spring load adjustment 60 is provided at the upper end of the spring, the adjustment making it possible to increase or decrease the level of tension in the spring and also to allow the spring to be shifted longitudinally. A slot 65 for complementary longitudinal adjustment is provided for the connection at the bottom of the spring. The launder is also connected to the pivot bearing 66 via the launder attachment 64. The position of the wheels can be varied along the longitudinally directed adjustment slot 69 to vary the height of the funnel.

The valve stem has a length adjustment 70a and terminates in a ball valve 71. It is opened and closed by the actuator 72. A heat resistant shield 73 shields the actuator from the hot metal in the launder and funnel portion.

Referring to Figure 5, the automatic skimmer 100 shown therein is particularly suitable for metal cast in smaller moulds particularly lead castings typically having a weight around 20 kilograms.

It includes a paddle 101 manufactured of a metal or ceramic which is capable of withstanding the high temperatures associated with the casting of metals and which is also resistant to corrosion under these conditions. The paddle includes a spoon like bend to assist in the removal of the dross at the end of a skimming stroke through a mould.

The paddle is clamped into the paddle clamp 105. Two nozzles 102 and 103 are positioned so that flames emanating therefrom impinge next to the lower corners of the paddle. The nozzles connect to a manifold 104 which is in turn secured to the rear plate 115 (fixation to the plate is omitted from the drawing for clarity). The nozzles are fed with oxygen enriched hydrocarbon gas.

The paddle clamp is supported by the paddle block clevis 108 via the pivot 106.

In turn, the paddle block clevis is mounted via the links 111 and 112 on the rear mounting plate 115. The links 111 and 112 are secured to the clevis via the pivots 109 and 110 and in turn to the rear mounting plate by the pivots 117 and 116.

A leaf spring 119 fitted inside a yoke 118 serves to resist sideways movement of the clevis and hence the paddle.

The paddle is spring loaded via the spring 114 connected immediately beneath the yoke 118 and to the linkage 107 by the rod 113.

The paddle is designed so that it is of slightly narrower width than a rectangular or square mould. Typically, when metal cools in a mould, it initially tends to solidify in an uneven manner along the sides of the mould. When the skimmer described above is pushed along the length of the mould, the flames from the nozzles help to melt any localised frozen or solidified material at the top and/or sides of the metal so improving the path or the paddle. However, should there still be any residual solidified metal against which the paddle might brush, the arrangement of pivotable links 111 and 112 which are spring loaded, allows some degree of side ways movement of the paddle to get past obstructions. Furthermore, the spring loading of the paddle via the spring 114 also allows pivotal movement of the paddle to help the paddle clear any obstruction.

Paddles of this sort may be secured to an automatic drive unit such as a robotic arm. One or more such paddles may be fitted to a robotic arm for being driven over one or more moulds containing molten metal to remove dross. The moulds can be moving on a conveyor or fixed in position. Applicants have successfully used the automatic skimmer shown herein at Pasminco Port Pirie Smelter since 28 April 1997. The skimmer device was fitted to an ABB robot and successfully skimmed 25 kilogram lead ingots on a casting conveyor.

Referring to Figures 6 and 6a, the pin lifting and removal assembly 199 shown therein is provided for removing pins 9 from a cast metal block 200. A pair of lifting hooks 206 are adapted to fit onto the head 8 of each pin 9. The lifting hooks are connected intermediate the length to the head bar 211 via the centre pivots 201.

The other ends of the lifting hooks are connected via the toggle pivots 205 to the toggle arms 203 and 203a. In turn, the toggle arms connect via the toggle pivot 202 to the lifting connector 204.

A toggle locking pin 212 is provided to lock the toggle arms in the configuration illustrated in Figure 6 when required. This may be a manually operated locking pin or it may include an automatically actuated pin (not shown).

Hydraulic cylinders 207 are provided on either side of the head bar 211.

During operation of the pin removal assembly, the hooks 206 are slid over the heads of the pins 9 and the assembly is lifted via the lifting connector 204. This has the effect of causing the toggle mechanism to pull the hooks towards the centre. Thus the pins are jammed in the block by the expansive force generated and the block can be lifted from a mould by the pins without the pins being dislodged. The stops 210 limit the degree of pivoting of the hooks.

To release the pins from the mould, the hydraulic cylinders 207 are used to push the block away from the pin. This is most suitably done by first resting the block on a support so that the toggle mechanism assumes the configuration shown in Figure 6 when the hooks do not exert an outward force across the block through the pins. When the block is rested on a support, the locking pin 212 may be inserted to prevent toggle action occurring when the hydraulic cylinders push the block away from the pins.

The locking pin will then be retained in the locked configuration until such time as the pins can be lifted for placement into a further mould prior to casting, the pins already having the desired configuration by virtue of the fact that they are held in the pin removal assembly at a fixed separation.

Referring to Figures 7 to 11, the automatic casting machine 300 includes a carousel 301 provided with a casting station 290, a skimming station 291, a transfer station 292 and a delivery station 293. A cooling area 294 is provided. This extends radially away from the transfer station. A pin removal station 295 having a delivery conveyor 296 and labelling and weighing station 357 are provided in association with the delivery station 293. An overhead crane assembly 297 connects the delivery station to the pin removal station.

The skimming station includes an automatic skimmer 302. Generally this will be in a form of a robot 303 operating a skimmer plate 304. Depending upon the nature of the metal being cast and the size of the moulds, the automatic skimmer 302 may be of quite different form to that shown in relation to Figure 4 which is more specifically directed to smaller mould casting operations particularly those involving small lead moulds (eg 25 kg moulds). A dross removal chute 308 is provided to dispose of dross removed by the automatic skimmer.

The transfer station 292 includes a first overhead crane assembly 315. The crane has a pair of pivotable crane arms 316 operable by an actuator 326 acting through toggle arms via the pivot 327. As can be seen from the drawing when the arms are in the vertical configuration they grab underneath the lip of the mould to support and carry a mould. However, when the toggle arms are operated in the reverse direction, the crane arms splay outwardly to let go of the mould.

The crane is provided with wheels 318 which run along the rails 319 so that it can move from above the transfer station 292 to the cooling area 294 where it can pick up and put down moulds. The cooling area includes a series of cooling tanks 12 each fitted with a water cooling system 317.

The first crane lifting assembly including actuator, toggle arms and crane arms is pivotally mounted via the pivot 320 for reasons to become apparent. The hydraulic cylinders 325 act to raise and lower the crane lifting assembly.

The second overhead crane assembly 297 includes hydraulic cylinders 355 for raising and lowering the block lifting and pin removal assembly 199 and the cast block or ingot 200 attached thereto. The crane moves between a position above the delivery station 293 to one above the delivery conveyor 296. It includes wheels 352 and rails 351 for this purpose.

A lift assembly 356 is provided underneath the carousel at the delivery station. The lift assembly includes two lifters 358 which may take the form of pneumatic cylinders. These lifters are arranged to push through openings provided in the carousel to lift the mould 1 clear of the carousel and cradle prior to being picked up by the lifting and removal assembly 199.

The carousel itself includes four mould cradles 310 for supporting the moulds by their circumferential lips 4. It also includes a support and drive mechanism 311 and a weighing assembly for weighing the metal being cast into a mould as it is cast by the launder 50. The carousel is controlled automatically and is powered by a variable speed electronic drive.

In a typical sequence of operations using the casting machinery shown in Figure 7, molten metal is poured from a fixed launder (not shown) into the tilting launder 50. The rate of delivery of molten metal through the funnel 52 of the tilting launder is controlled by the degree of tilt which is in turn dependent upon the weight of metal in the launder, the degree of tilt determining the amount of opening of valve 71.

When the weight of metal poured into the steel mould 1 as measured by the weighing assembly 312 reaches a predetermined limit, the actuator 72 automatically closes off valve 70 and the hydraulic cylinder 54 lifts the launder clear of the mould.

The carousel then rotates anti-clockwise to index the mould 1 now filled with molten metal to the skimming station 291. The acceleration and deceleration of the variable speed drive rotating the carousel is carefully controlled each time it indexes the moulds to a different station in order to minimise the surface wave actions induced in the molten metal. The carousel may also be provided with a mould cooling jacket (not shown) at the casting station to allow cooling to begin immediately after the initiation of pouring in order to minimise the elapsed cooling time and also minimise the thermal shock to the steel moulds.

The rate of acceleration and deceleration versus time applying as the moulds are indexed to the different stations may be in accordance with a sinusoidinal velocity versus time relationship.

The skimming station 291 may also be provided with a mould cooling jacket (not shown) to further cool the mould at the station. The robot 303 of the automatic skimmer 302 moves a skimmer plate 304 across the surface of the mould to pick up dross and dump it in the dross removal chute.

Following removal of dross, the mould is indexed to the transfer station 292. At the transfer station the overhead crane 315 through operation of the hydraulic cylinders 325 lowers the crane arms which are held in the splayed position by the actuator 326 as they are being lowered.

When the crane arms are in registry with the lip of the mould, the actuator 326 operating through the pivot 327 by a toggle action moves the crane arms into gripping registry with the lip of a mould and the mould is subsequently lifted by actuation of the hydraulic cylinders 325 clear of the cradle 310.

The crane then travels along the rails 319 until it approaches an empty cooling tank 12. It decelerates to a stop above the empty tank and lowers the mould with molten metal into the tank, the acceleration and deceleration of the crane being again controlled in accordance with a sinusoidinal velocity versus time relationship. The pivot 320 provided in association with the assembly for holding the arms of the crane allows the crane holding the mould to freely sway from the vertical during the acceleration and deceleration phases. This swaying action in association with the controlled acceleration/ deceleration serves to reduce the amount of disturbance felt by the molten metal in the mould during the travel to the cooling tank and hence minimises ripples.

After the mould has been placed in the cooling tank and the crane arms are retracted to their uppermost position, the crane moves to a tank where the mould has had sufficient cooling, and after the lid 13 has been tilted aside, picks up the mould and deposits it on the cradle 310 of the carousel at the transfer station.

This cooled mould is then indexed to the delivery station 293 by the carousel where it is lifted clear of the cradle via the lift assembly 356.

Upon being lifted clear of the cradle, the overhead crane 350 moves the pin removal assembly 199 into registry with the pins 9 such that the two lifting hooks 206 attach under the head of the pins.

The hydraulic cylinders 355 then lift the pin removal assembly via the lifting connector 204 and by the lifting action cause a toggle action which presses the two pins towards each other to "jam" them in the cast block as it is lifted out of the mould. The retracted crane then moves the cast block which has been lifted clear of the mould to the pin removal station 295 where it is placed on the delivery conveyor 296 and the toggle locking pin 212 is actuated to prevent the toggle action from locking the pins in the block any longer. The hydraulic cylinders 207 push the ingot free of the pins onto the conveyor and the pins are returned by the crane assembly 297 to be placed in the empty mould still at the delivery station 293. The empty mould at the delivery station 293 may also be sprayed with a release agent before indexing to the casting station in order to assist the release of subsequently cast blocks from the mould.

Following placement of the pins in the empty mould, the mould is indexed back to the casting station 290 for the entire cycle to be repeated. It is to be appreciated that the steps at the various stations around the carousel are carried out concurrently.

The delivery conveyor moves the de-pinned block to the weighing and labelling station 357 and subsequently to a further location for pick up and delivery to a customer.

While it has been convenient to describe the invention herein in relation to particularly preferred embodiments, it is to be appreciated that other constructions and arrangements are considered as falling within the scope of the invention. Various modifications, alterations, variations and/or additions to the constructions and arrangements described herein are also considered as falling within the scope and ambit of the present invention.

CLAIMS

1. Apparatus for the casting of metals, having a sequential drive for indexing moulds provided thereon to a plurality of stations, the plurality of stations including:-

a casting station for casting molten metal into a mould;

a transfer station provided with transfer means for transferring a mould containing molten metal cast into the mould at the casting station to a cooling facility separate from the sequential drive and return means for returning a cooled mould containing solidified metal ingot from the cooling facility to the sequential drive; and

a delivery station provided with removal means for removing the solidified metal ingot from the sequential drive leaving an empty mould on the sequential drive for return to the casting station.

2. Apparatus according to claim 1 including a skimming station located intermediate the casting station and transfer station, the skimming station being provided with means for skimming dross from molten metal contained in a mould.

3. Apparatus according to claim 1 wherein the casting station includes a launder for delivering molten metal to a mould and weighing means for weighing the weight of metal delivered to the mould, the launder having valve means which is adapted to cut-off delivery of molten metal to the mould when the weighing means registers a weight of metal in the mould at or beyond a predetermined weight limit.

4. Apparatus according to claim 3 wherein the launder includes control means responsive to the weight of metal in the launder, the control means controlling the degree of opening of the valve means to control the rate of flow of metal from the launder to the mould.

5. Apparatus according to claim 3 wherein the launder includes an elongate metal reservoir terminating in a funnel provided with a discharge opening for delivery molten metal to a mould, the discharge opening being provided with a ball valve for controlling metal flow therethrough.

6. Apparatus according to claim 1 wherein the sequential drive includes a carousel provided with cradles to hold moulds.

7. Apparatus according to claim 1 wherein the transfer means and return means include an overhead transfer crane for picking up a mould containing molten metal from the sequential drive and replacing it with a mould containing a solidified metal ingot and the cooling facility includes one or more cooling tanks located apart from the sequential drive.

8. Apparatus according to claim 7 wherein the overhead transfer crane includes crane drive means for driving the crane between the cooling facility and transfer station the crane drive means being adapted to accelerate and decelerate according to an acceleration/deceleration versus time relationship which is substantially sinusoidinal, and a pick up assembly adapted to pick up and put down moulds at the transfer station and cooling facility, the pick up assembly being pivotally mounted on the crane in such a manner as to allow a mould being held by the assembly to sway in response to acceleration and deceleration of the overhead transfer crane.

9. Apparatus according to claim 1 wherein the removal means includes a delivery crane provided with a lifting assembly for lifting a solidified metal ingot clear of a mould at the delivery station and transferring it to a supply station.

10. Apparatus according to claim 9 wherein the removal means includes a lifting assembly for picking up and removing a solidified metal ingot by attachment to one or more pins provided in the mould when the molten metal for forming the solidified metal ingot is cast from the mould and delivering it to a supply station.

11. Apparatus according to claim 10 wherein the pins include a head portion and a tapered body portion for which the narrower end of the taper points downwardly in the mould and the lifting assembly includes pressure means for providing pressure between the solidified metal ingot and pins to generate sufficient frictional engagement between the pins and ingot as to allow the ingot to be lifted from the mould by the head portion of the pins without the pins separating from the solidified ingot.

12. Apparatus according to claim 11 wherein there are two pins and the pressure means include a pair of hooks which attach underneath the head of the respective pin, the hooks also being attached to a toggle assembly for applying compressive or expansive pressure via the hooks and pins to promote frictional engagement with the solidified metal ingot, the toggle assembly also including pushing means to push the solidified metal ingot from the pins after it has been delivered to the supply station.

13. Apparatus according to claim 12 wherein the toggle assembly includes locking means which lock the toggle assembly in a configuration in which pressure via the hooks is not applied between the pins and the removal means is adapted to return the removed pins to the empty mould remaining at the delivery station.

14. Apparatus according to claim 10 wherein the supply station includes a conveyor for the metal ingots and a weighing and marking facility for metal ingots placed on the conveyor.

15. Apparatus according to claim 2 wherein the skimming station includes a skimmer having a skimming paddle and one or more flame nozzles for directing flames towards the paddle.

16. Apparatus according to claim 15 wherein the paddle includes a curved skimming portion and the paddle is spring loaded to allow the paddle to pivot about an axis of rotation perpendicular to the direction of travel of the paddle as it is pushed along the surface of molten in a mould to remove dross and the paddle is also spring loaded in a direction substantially perpendicular to the direction of travel to permit a degree of sideways play of the paddle as it is pushed along the surface.

17. Apparatus according to claim 4 wherein the transfer means and return means include an overhead transfer crane for picking up a mould containing molten metal from the sequential drive and replacing it with a mould containing a solidified metal ingot and the cooling tanks are located apart from the sequential drive.

18. A method for the casting of metals including the steps of:-

indexing a mould in series on a rotating carousel to a casting station, a skimming station, a transfer station and a delivery station;

casting molten metal into the mould at the casting station;

skimming dross from the molten metal at the skimming station;

transferring the mould containing molten metal from the transfer station to a cooling station remote from the transfer station and replacing it at the transfer station with a cooled mould containing a solidified metal ingot from the cooling station;

removing the solidified metal ingot from the cooled mould at the delivery station; and

returning the cooled mould less solidified metal ingot to the casting station.

19. A method according to claim 18 wherein the mould at the casting station is provided with a pair of pins around which the metal is cast, the pins are removed from the solidified metal ingot when it is removed from the mould at the delivery station, and the pins are replaced in the cooled mould at the delivery station to be returned with the cooled mould to the casting station.

20. A method according to claim 19 wherein the weight of metal cast into the mould is measured and controlled within predetermined limits at the casting station.

21. A method according to claim 18 wherein the mould containing molten metal is picked up from the transfer station, accelerated to move it from the vicinity of the transfer station and decelerated to rest above a cooling tank in which it is deposited to cool, the acceleration and deceleration being substantially in accordance with an acceleration/deceleration versus time relationship which is substantially sinusoidinal.

22. A launder for molten metal including:-

an elongate reservoir provided with an outlet for the discharge of molten metal therefrom;

valve means for controlling the discharge of molten metal through the outlet; and

control means responsive to the weight of molten metal in the launder to control the valve means and the rate of discharge of molten metal.

23. A launder according to claim 23 wherein the valve means includes a ball valve provided at the outlet, the ball of said valve being connected by a valve stem passing through a funnel connected to the outlet to an actuator for opening and closing the ball valve.

24. A launder according to claim 22 wherein the launder is tiltable and the control means include a lever mechanism responsive to the degree of tilt to control the valve means.

25. A launder according to claim 24 wherein the valve means includes a valve element for controlling and stopping discharge of molten metal through the outlet, the valve element being connected by a valve stem passing through a funnel connected to the outlet to an actuator for opening and closing the valve means.

26. A launder according to claim 25 wherein the launder is pivotally mounted near an end opposite the end provided with the outlet, and a compressible support mechanism supports the launder near the outlet end, the lever mechanism being responsive to the degree of compression of the compressible support mechanism to raise or lower the valve stem whereby to control the rate of discharge of molten metal.

27. A launder according to claim 23 wherein the launder is tiltable via a pivotal support provided near one end of the launder and the control means supports the launder near its other end and includes an elongate bar which is pivotally mounted on the launder by a bar pivot provided intermediate its ends, the elongate bar being connected to the valve stem at one end and to one end of a double ended spring mechanism at its other end, the other end of the spring mechanism being attached to the launder, a support foot provided on the elongate bar between the pivotal launder mounting and the connection of the bar to the valve stem the arrangement being such that the weight of the launder containing molten metal presses down on the bar pivot to urge the elongate bar to rotate so as to lift the valve stem and open the valve, the spring mechanism acting to resist such rotation.

28. A launder according to claim 27 wherein the spring mechanism is adjustable to vary the degree of rotation obtainable with a given weight of launder.

29. A skimmer for molten metal including a skimming paddle and one or more flame nozzles arranged to direct flames towards the paddle.

30. A skimmer according to claim 29 wherein the skimming paddle includes a curved portion and the paddle is spring loaded to allow the paddle to pivot about an axis of rotation perpendicular to the direction of travel of the paddle as it is pushed along the surface of molten metal in a mould to remove dross.

31. A skimmer according to claim 30 wherein the paddle is spring loaded in a direction substantially perpendicular to the direction of travel to permit a degree of sideways play of the paddle as it is pushed along the surface.

32. A lifting and removal assembly for lifting metal ingots cast with a pair of pins and removal of the pins therefrom, the pins having a head provided above a tapered body portion around which the metal has been cast in a mould with the narrower end of the tapered body portion pointing downwardly, the lifting and removal assembly including:-

hook means for attachment to the heads, pressure means for generating pressure between the pins and ingot sufficient to allow the assembly to lift the ingot from a mould by attachment of the hook means to the heads without the pins separating from the ingot; and

pushing means adapted to push against the ingot to separate the ingot from the pins held by the hook means.

33. A lifting and removal assembly according to claim 32 wherein the hook means include a pair of hooks for attachment to the respective head and the pressure means includes a toggle assembly attached to the hooks, the toggle assembly being adapted to push the ends of the hooks and the heads of the pins towards or away from each other.

34. A lifting and removal assembly according to claim 33 wherein the hooks include a hook end and a toggle end and the toggle assembly includes:-

a pair of toggle bars each pivotally joined by a central pivot to each other at one end and to the toggle end of a respective hook at the other end; and

a head bar pivotally joined to each hook at a position intermediate the hook end and toggle end.

35. A lifting and removal assembly according to claim 34 wherein the pushing means includes a pair of hydraulic or pneumatic cylinders mounted on the head bar and the lifting and removal assembly includes a locking bar which is attached to the toggle bars and extends to be removably attached to the head bar in such a manner as to prevent the toggle assembly from preventing the hook ends and heads being pushed towards or away from each other.

36. Apparatus according to claim 1 substantially as hereinbefore described with reference to the accompanying drawings.

37. A launder according to claim 22 substantially as hereinbefore described with reference to the accompanying drawings.

38. A skimmer for molten metal according claim 29 substantially as hereinbefore described with reference to the accompanying drawings.

39. A lifting and removal assembly substantially as hereinbefore described with reference to the accompanying drawings.

40. A method for the casting of metals according to claim 18 substantially as hereinbefore described.

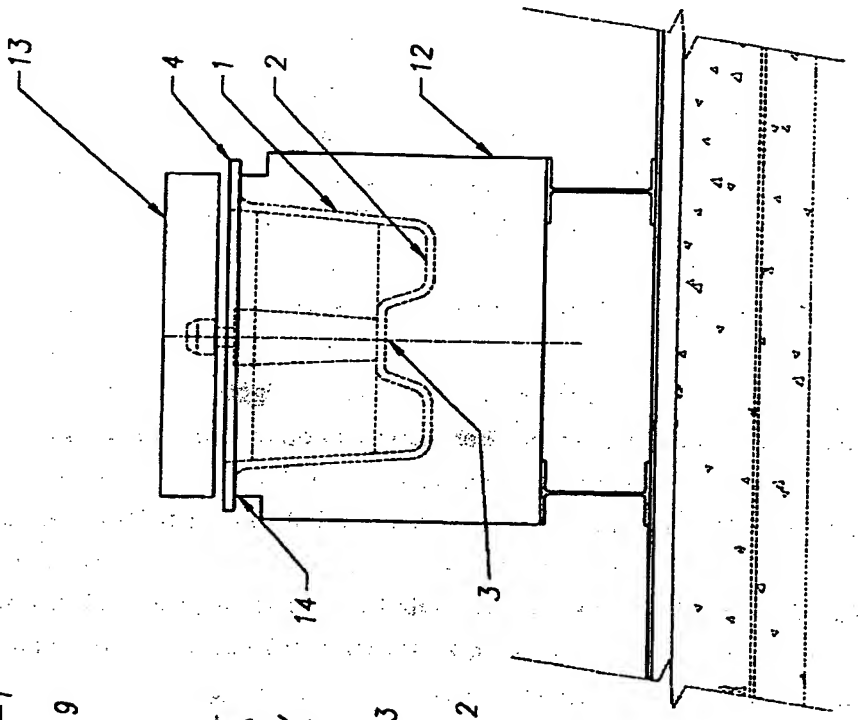

FIGURE 1c

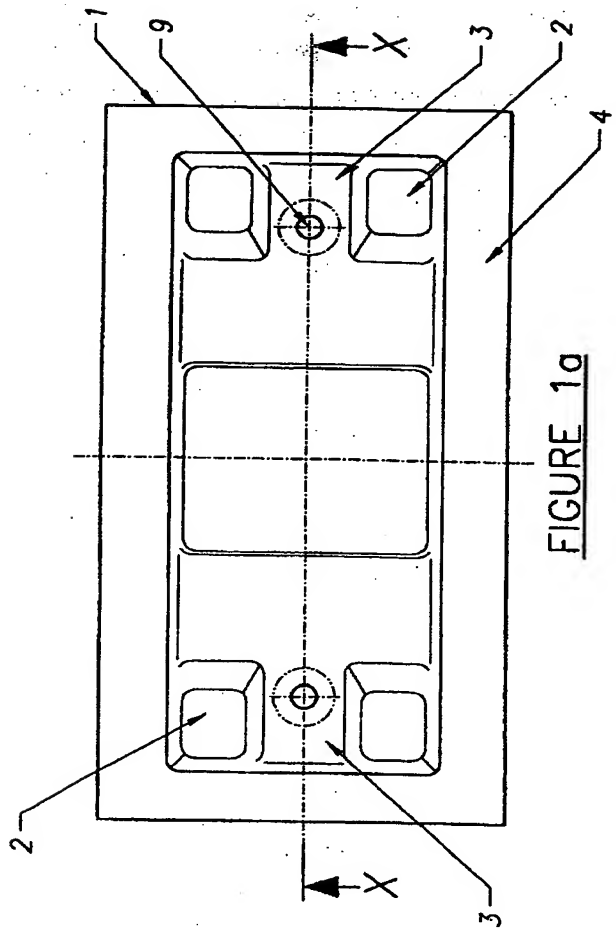

FIGURE 1a

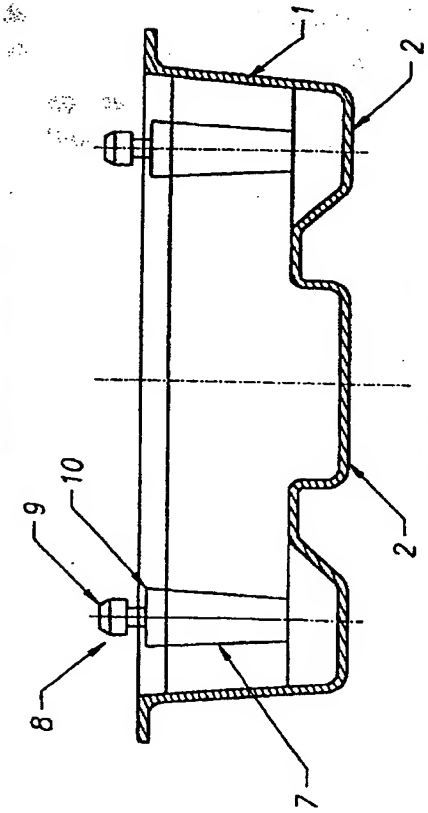

FIGURE 1b

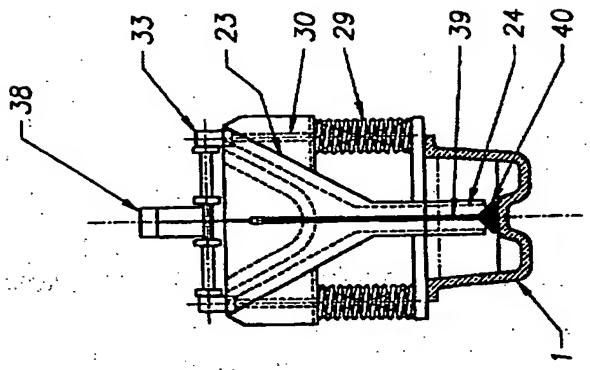

FIGURE 2b

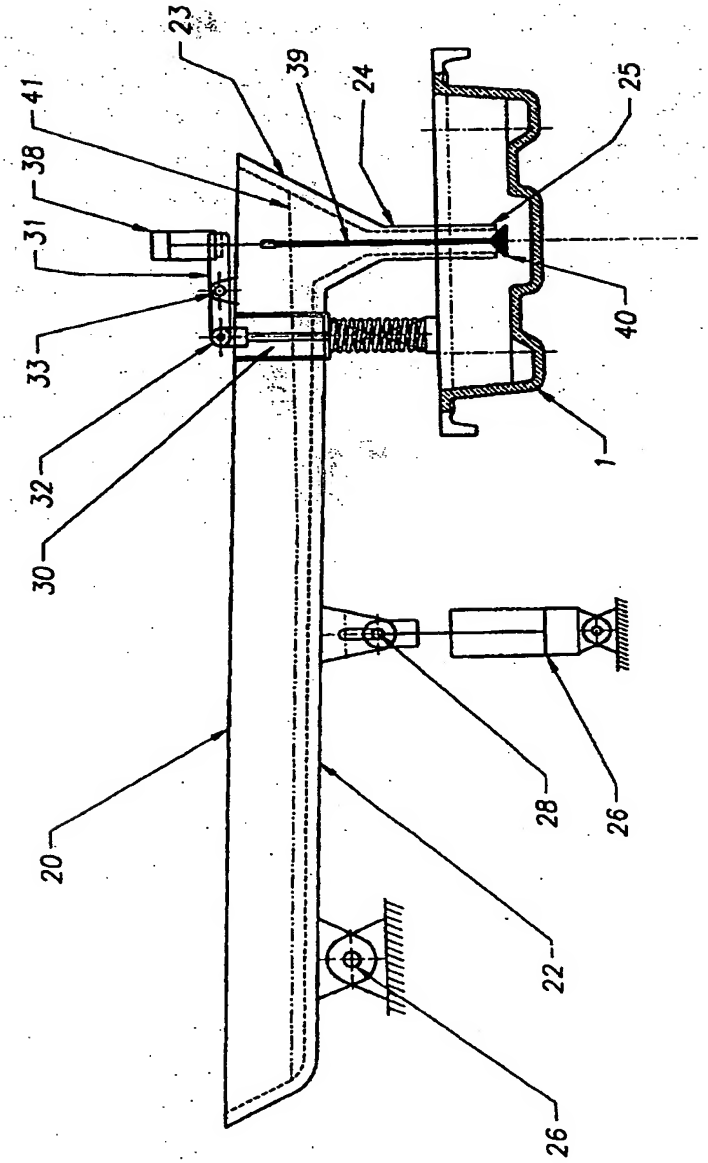

FIGURE 2a

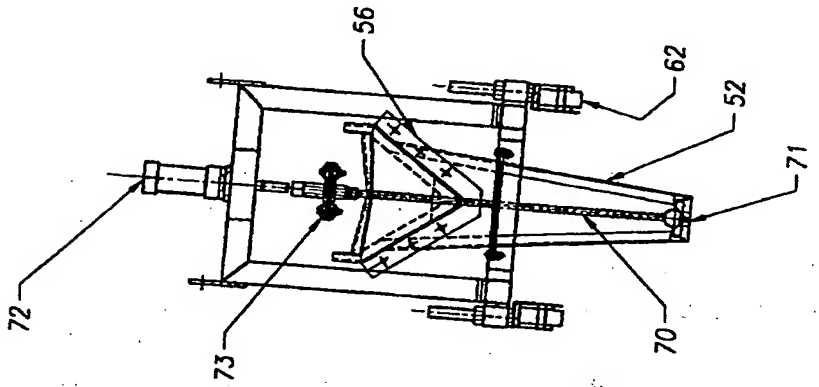

FIGURE 4

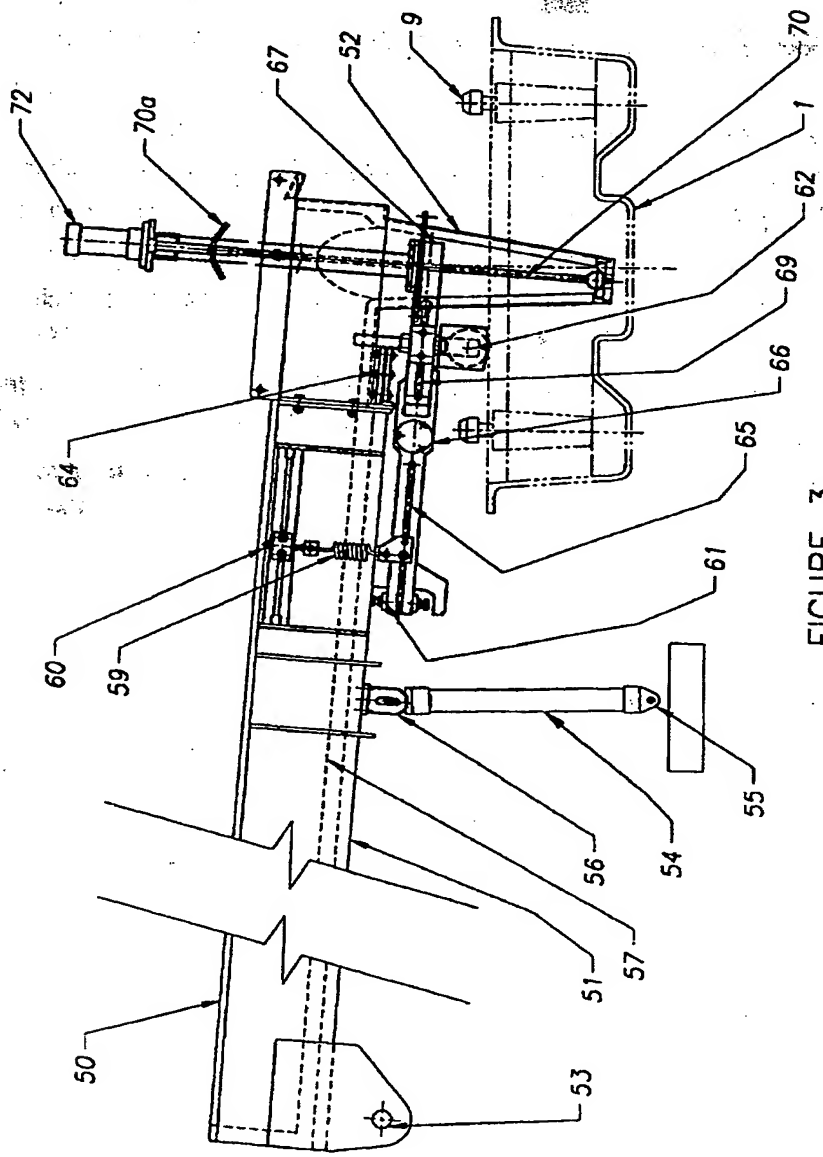

FIGURE 3

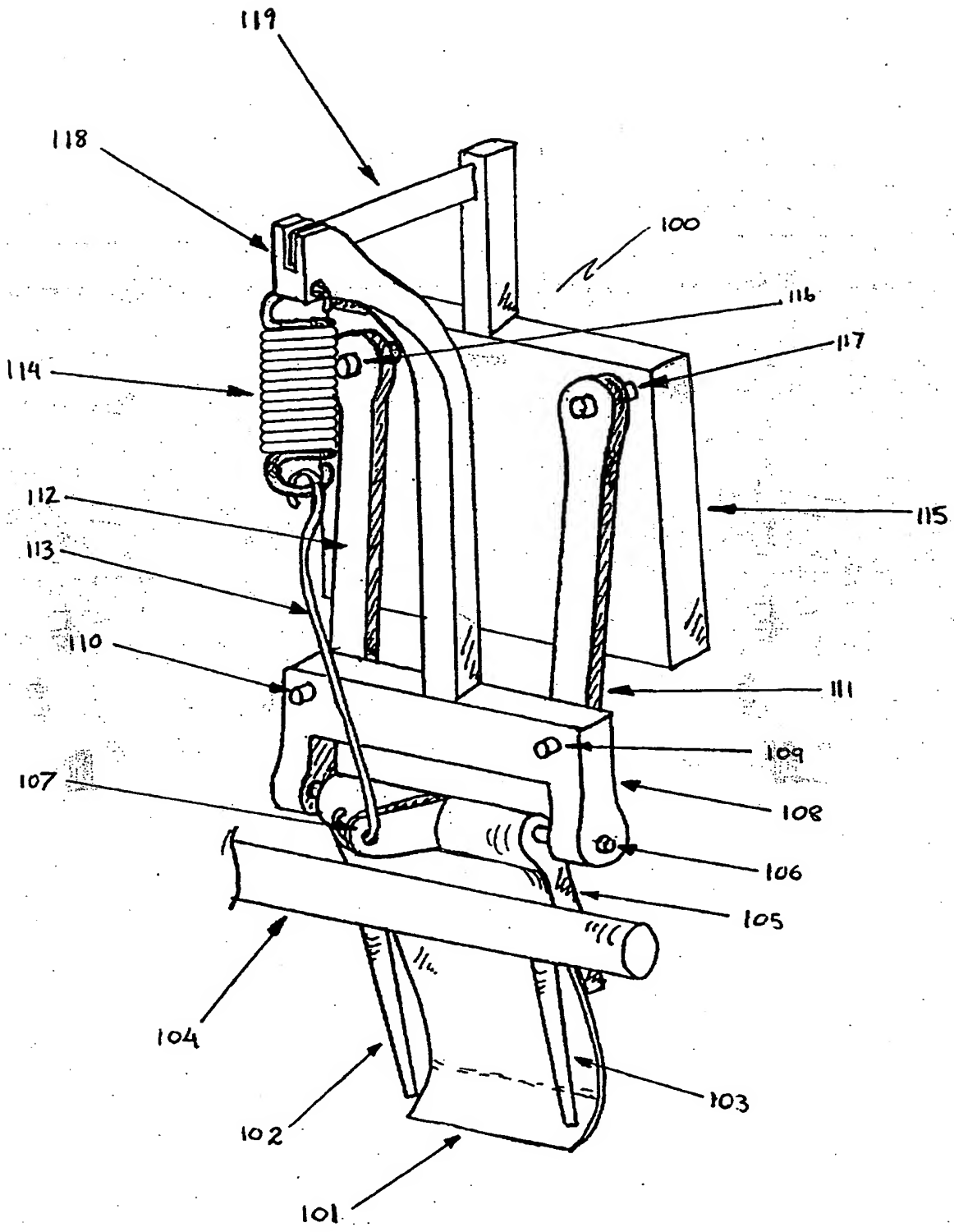

FIGURE 5

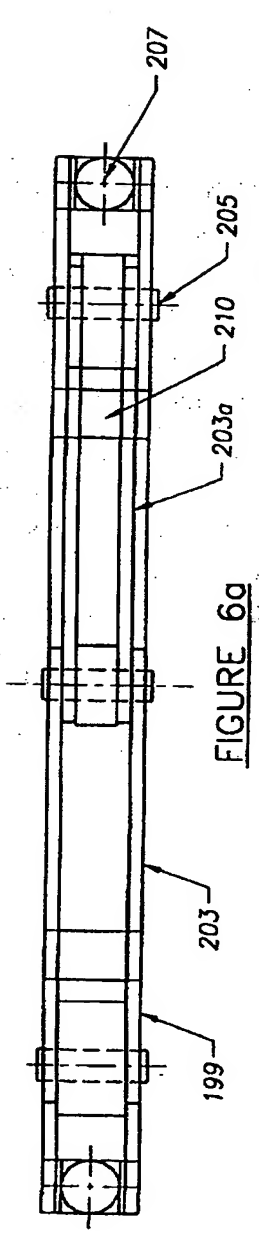

FIGURE 6a

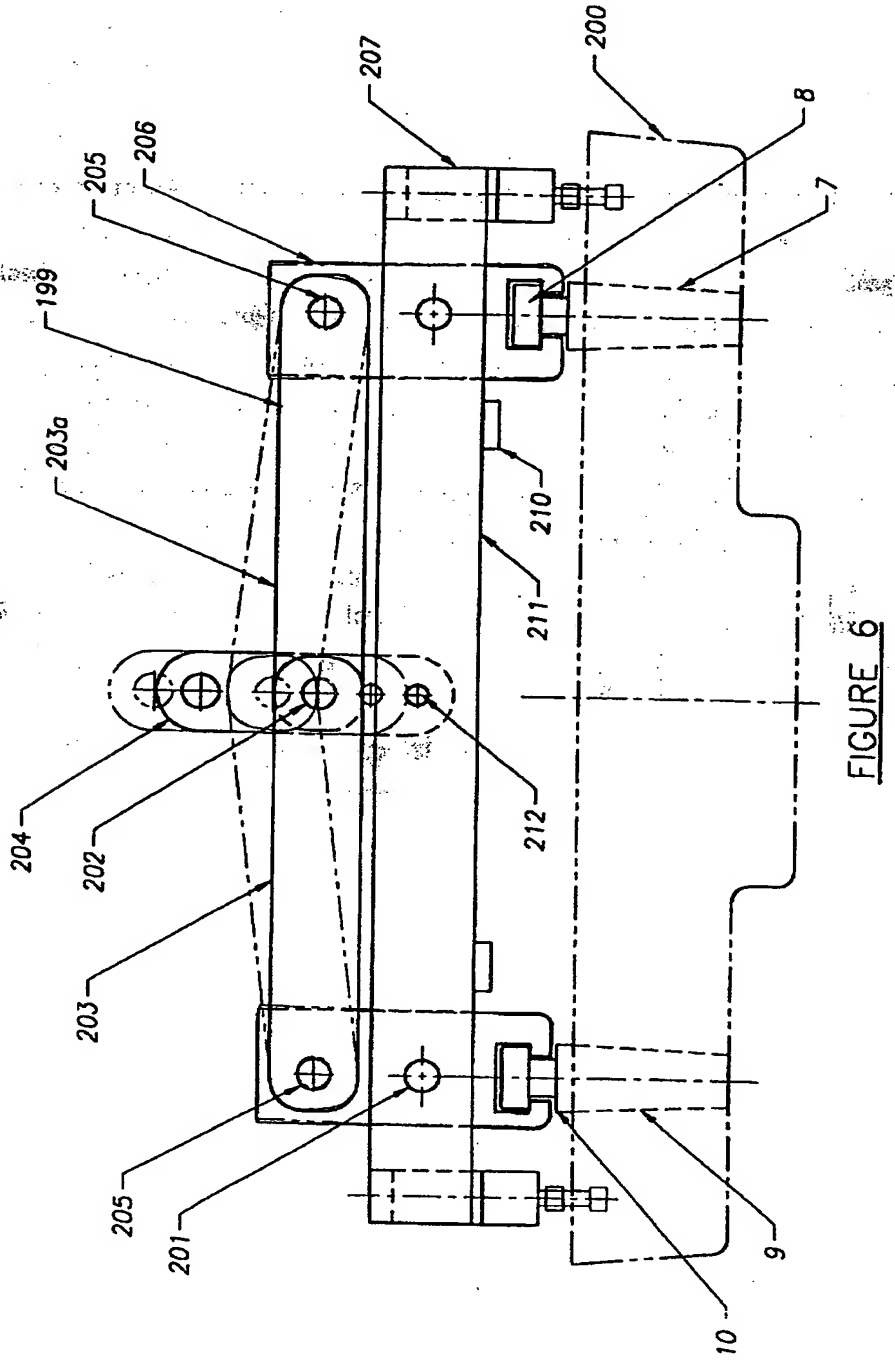

FIGURE 6

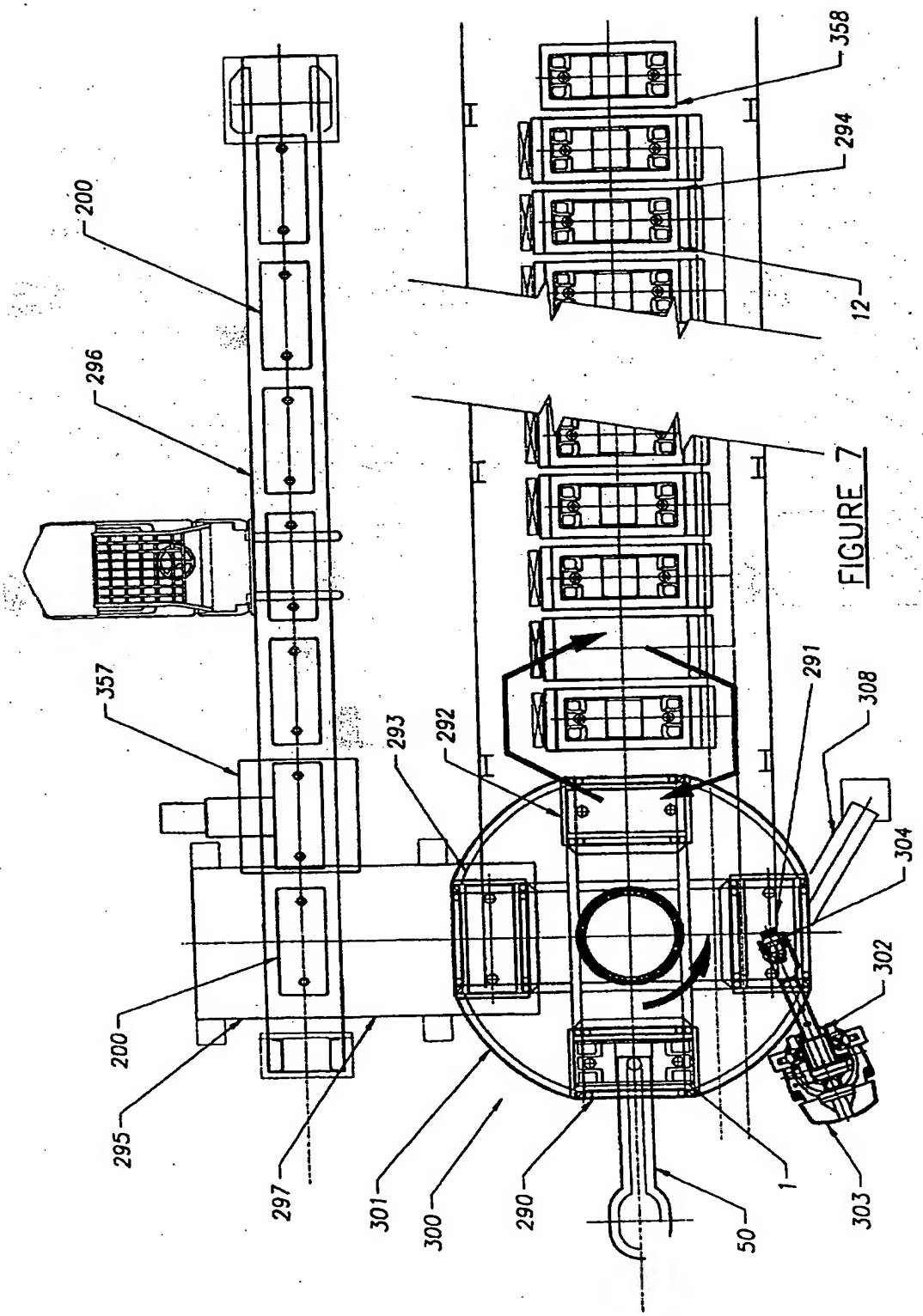

FIGURE 7

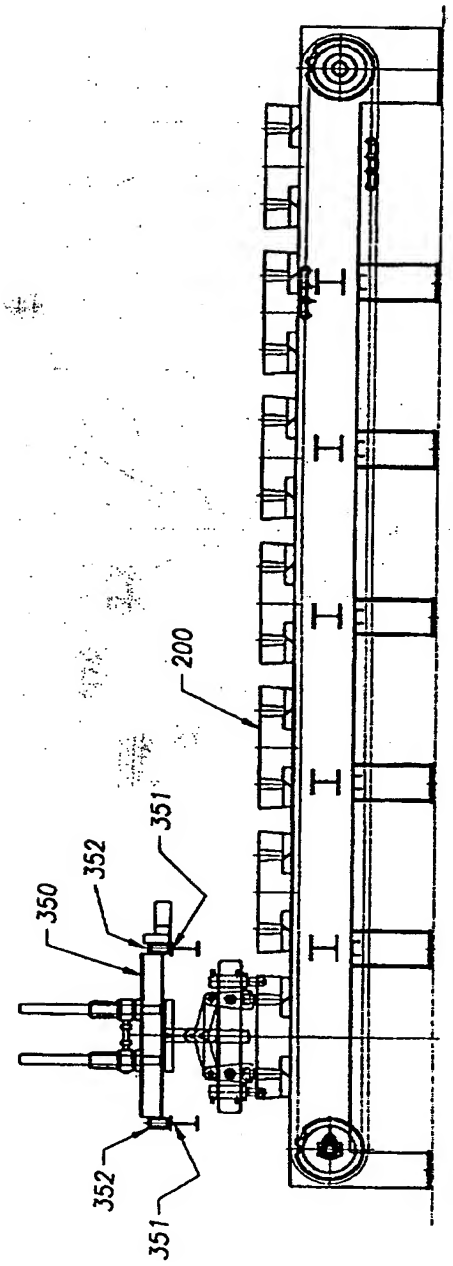

FIGURE 10

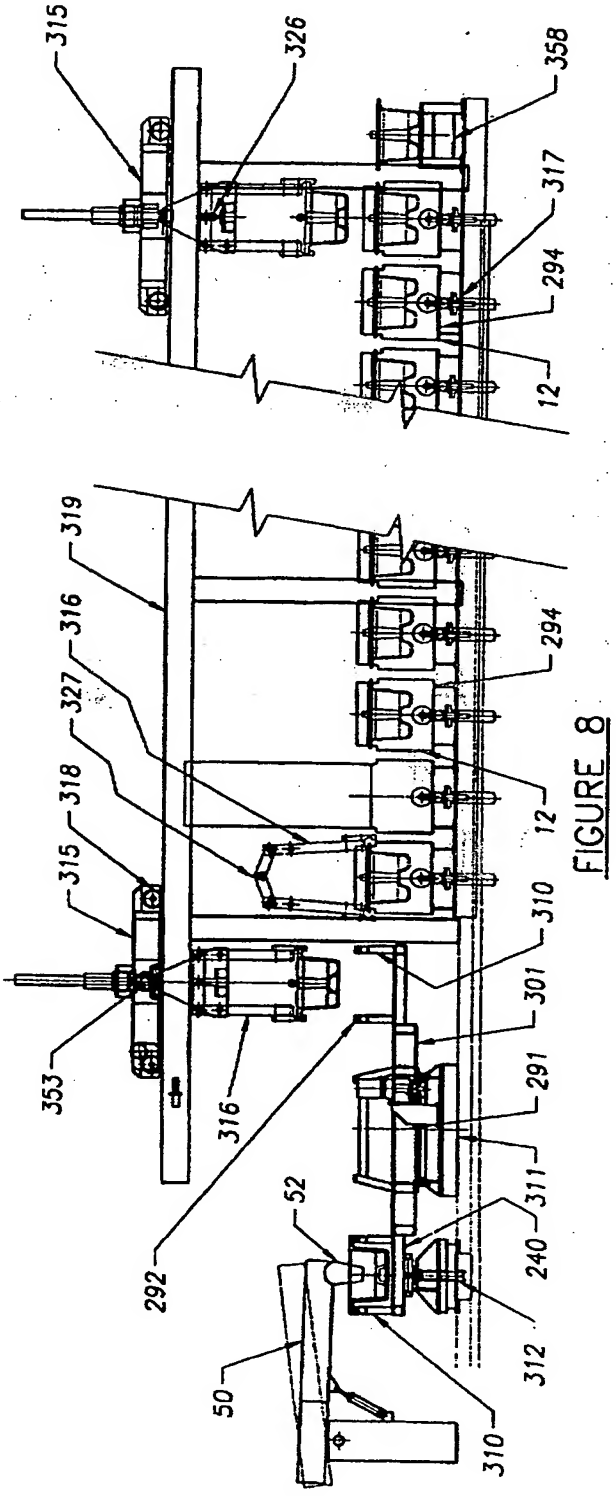

FIGURE 8

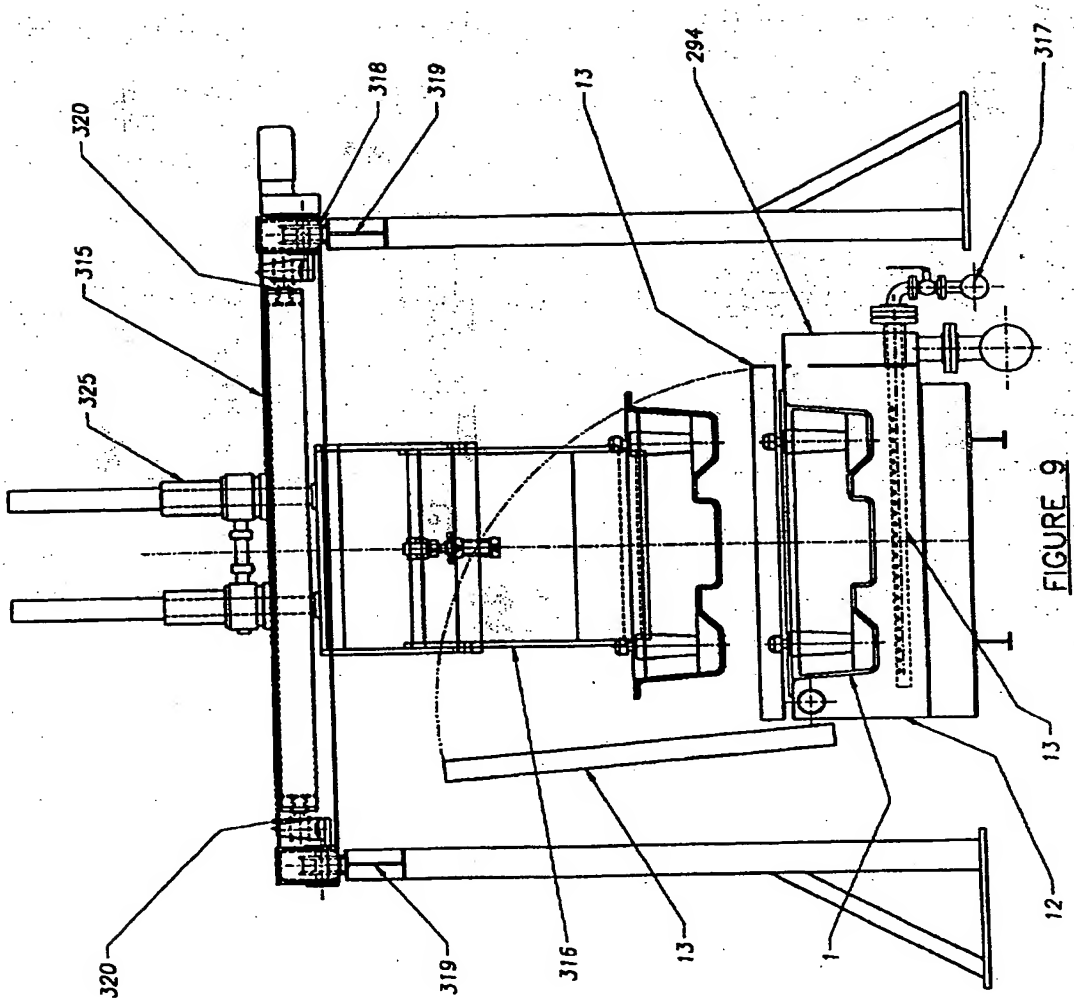

FIGURE 9

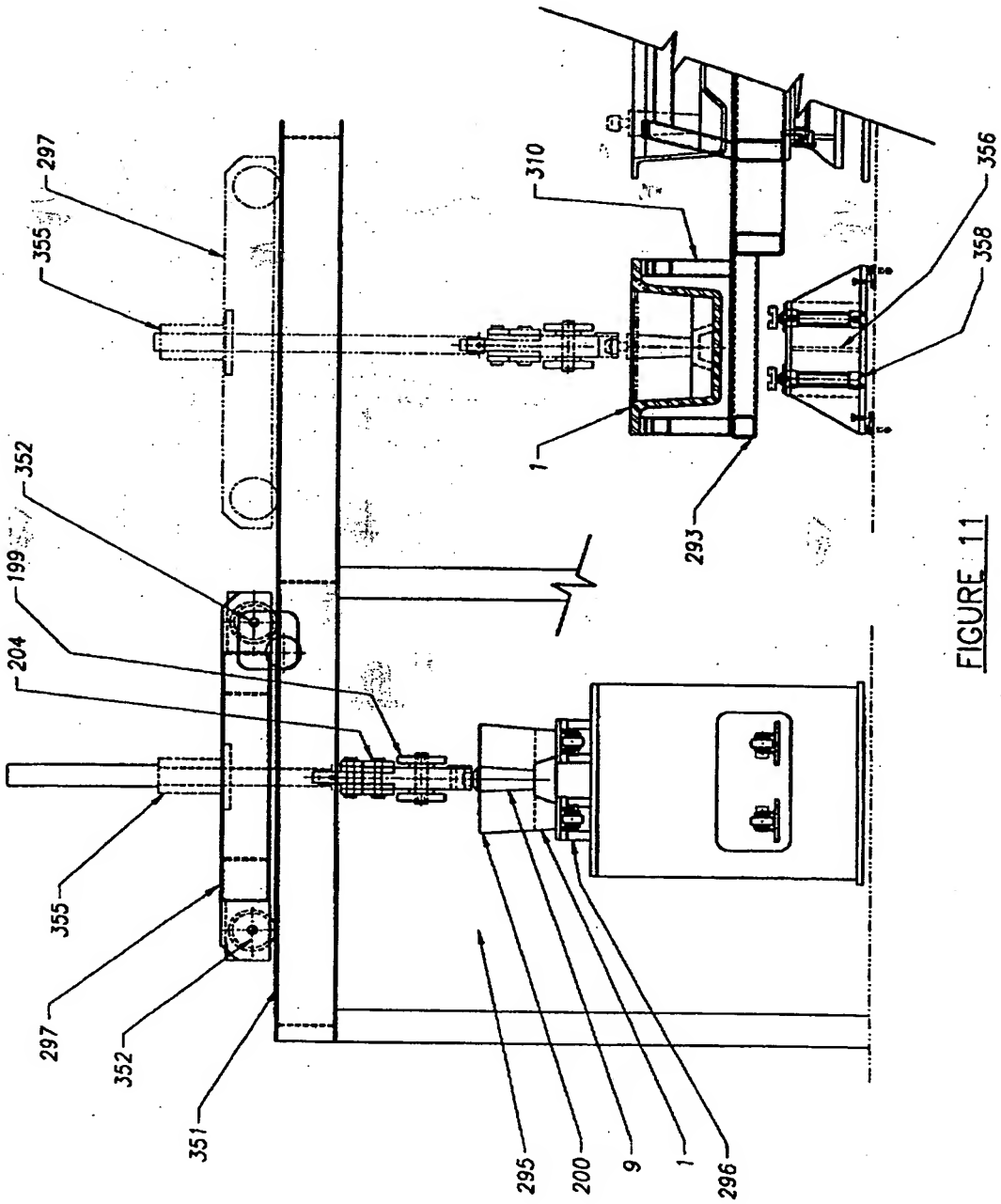

FIGURE 11